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(52) Lens system usable in the IR.

(57) A lens system for imaging infra-red radiation comprises two elements, one of Zinc Selenide (1.6) and the other of either Zinc Sulphide (2) or Caesium Bromide (5). Lens configurations are shown which allow imaging at a common image plane over at least both the 3-5 μ m and 8-12 μ m optical wavebands.

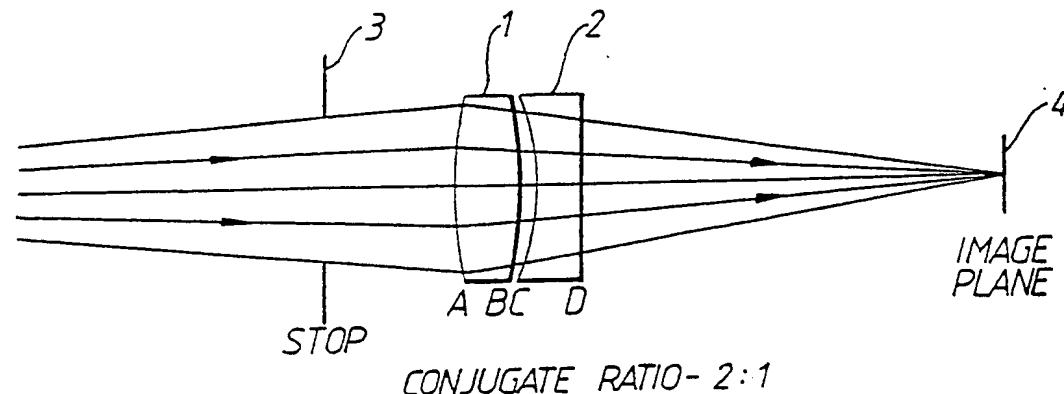


FIG. I.

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Lens Systems

This invention relates to lens systems, and in particular it relates to lens systems for use with infra-red radiation.

As is well known, all optically transmissive materials have a refractive index, $n(\lambda)$, and a corresponding reciprocal dispersive power or V-value, which are associated respectively with the wavelength λ and a defined wavelength interval $\Delta\lambda$. The variation of the refractive index with wavelength results in a single lens exhibiting chromatic aberration i.e. the degree of refraction being dependent upon the wavelength of the refracted radiation. In general, if it is required to bring two different wavelengths to a common axial focus, then two optical materials of different V-values are required. Similarly three materials of different V-values are generally required to focus three different wavelengths and so on.

Optical systems for use with the far infra-red band (generally 8 to 12 μ m) usually employ germanium as the sole optical material. Although only one wavelength may be brought to a common focus within a system employing only germanium elements, it is generally recognised that due to the relatively high V-value of germanium, about 1000, chromatic dispersion will be small enough to ignore in most applications. However, several more recent applications and the use of more complex designs require the chromatic dispersion to be corrected so that for example two wavelengths may be brought to a common focus. In these cases another material such as zinc selenide (ZnSe) or zinc sulphide (ZnS) is combined with the germanium. Systems such as this are generally used when two wavelengths within the far infra-red band, such as eight μ m and eleven μ m, are to be brought to a common focus.

Recent advances in electro-optical system have led to a requirement that the optical system be adapted to bring radiation from both 3 - 5 μ m and 8 - 12 μ m wavebands to a common focus to within the limit prescribed by the "Rayleigh Quarter-Wave Rule". Current methods of achieving this involve the use of at least three different materials in the optical system, generally comprising ZnS, ZnSe and Ge. It has not previously been thought possible that a lens system satisfying these requirements can be produced from only two materials.

According to the present invention there is provided a lens system comprising one or more lens elements composed of Zinc Selenide (ZnSe) and one or more lens elements composed of one of Zinc Sulphide (ZnS) or Caesium Bromide; con-

figured so as to produce images at a common image plane, at least over both the 3-5 μ m and 8-12 μ m optical wave bands.

In a first preferred embodiment the lens sys-

tem comprises one element composed of Zinc Selenide and a second element composed of Zinc Sulphide. The system may comprise a first lens composed of Zinc Selenide and having an equi-biconvex structure, separated from a second lens by a relatively narrow air gap, the second lens having a concave meniscus structure and being composed of Zinc Sulphide.

It is found that such an optical system can provide good imagery in at least both the chosen wavebands and would generally also provide imagery at visible wavelengths down to perhaps 0.5 μ m or even less. Since only two different optical materials are used the system is relatively easy to implement.

In a second preferred embodiment of the invention the system comprises one Zinc Selenide element and one Caesium Bromide element.

The system may comprise a biconvex Caesium Bromide front lens of positive optical power separated by a relatively narrow air gap from a second Zinc Selenide lens of negative optical power.

Preferably the second lens is meniscus in section.

This construction can, similarly to the first, provide good imaging over the chosen wavebands.

Embodiments of the invention will now be described by way of example only with reference to the accompanying drawings in which:

Figure 1 shows a first lens system according to the invention.

Figure 2 indicates the dimensions of the structure shown in Figure 1.

Figure 3 shows a second lens system according to the invention, and:

Figure 4 indicates the dimensions of the system of Figure 3.

Referring to Figure 1 a lens system according to the first embodiment of the invention comprises a first lens 1 composed of Zinc Selenide and a second lens 2 composed of Zinc Sulphide. An aperture stop 3 is provided in front of the lenses and transmitted radiation is arranged to come to a focus to an image plane 4.

The first lens 1 is constructed in this particular embodiment to be equi-biconvex with the radius of both faces being 36.51, as is indicated in Figure 2. In this figure: the 'radius' column relates to the radius of curvature of the particular surface in-

dicated; 'thickness' is the separation between that surface and the following one; 'aperture' relates to the diameter of that surface, such that the diameter is 2 times the aperture, and; the 'material' column shows which optical material is between that surface and the following one. Thus, the system comprises the first lens 1 of equi-bi-convex structure with radii of curvature 36.51, separated by an air gap of 0.965 from the second lens 2 of Zinc Sulphide which has a first negative curvature of 26.13 and a second face of negative curvature 167.67.

The system is arranged in this way to have a conjugate ratio, i.e. the ratio between object and image planes, of 2 to 1. The Zinc Sulphide lens may also be manufactured from any other material with similar chemical composition, such as a product which is a pure form of Zinc Sulphide, known under the Trade Mark Cleatran, which trade mark is the property of CVD Inc, Woburn, MA01801; or Multispectral, which is a product of Schott Glaswerke. The construction shown in Figures 1 and 2 will produce a lens system which will provide an image scale of 0.5 times the object scale and provide near diffraction limited imaging performance on axis over both the 3-5 μ m and 8-12 μ m transmission wave bands, measured at a common image plane.

It should however be noted that many other lens systems may be constructed within the scope of the invention to have different gaussian properties such as equivalent focal length, which in this case is 24.58, or magnification, but which would still retain the use of only ZnSe and ZnS in the optical elements.

Figures 3 and 4 show a second, alternative, embodiment comprising a first and second lens 5 and 6 respectively, of which lens 5 is a biconvex lens of positive optical power manufactured from Caesium Bromide and rear lens 6 is of negative optical power, meniscus in section, and manufactured from Zinc Selenide. The exact dimensions of the system are shown in Figure 4 in a similar manner to that of Figure 2.

This second embodiment is adapted to have a conjugate ratio of infinity to one and to have an equivalent focal length of 124.969. As with the first above described embodiment, it should be noted that other configurations may be envisaged within the scope of this second aspect of the invention which may include more lenses or be adapted for use with different wavelength radiation. The embodiments shown in Figure 3 can again achieve diffraction limited performance over the two wavebands 3-5 μ m and 8-12 μ m, measured at the same image plane in both cases.

It should be noted that the use of either ZnSe and CsBr, or ZnS and ZnSe alone will significantly

reduce the thermal variation of the axial location of an optical image. In this regard, previous systems which included germanium in the optical system did tend to suffer from thermal variation of the optical performance. The systems disclosed herein do not tend to suffer to such a great extent as germanium.

It should also be noted that optical systems in accordance with the invention herein can be constructed to operate over not only the 3-5 μ m waveband and 8-12 μ m waveband but also may provide good imagery at visible wavelengths down to perhaps 0.5 μ m.

A lens system in accordance with either embodiment of the invention may advantageously be used as the refractive element in a Thermal Imager.

20 Claims

1. A lens system comprising one or more lens element (1.6) composed of Zinc Selenide and one or more lens elements (2.5) composed of one of Zinc Sulphide or Caesium Bromide; the lens elements forming one optical path and being configured so as to produce images, at a common image plane, at least over both the 3-5 μ m and 8-12 μ m optical wavebands.

2. A lens system as claimed in claim 1 comprising one Zinc Selenide lens element (1) and one Zinc Sulphide (2) lens element.

3. A lens system as claimed in claim 2 comprising a first Zinc Selenide lens of equi-biconvex structure, and a second Zinc Sulphide lens of negative optical power; the two lenses being separated by a relatively narrow air-gap.

4. A lens system as claimed in claim 2 having the structure shown in Figure 2 of the accompanying drawings.

5. A lens system as claimed in claim 1 comprising one Zinc Selenide lens element (6) and one Caesium Bromide lens element (5).

6. A lens system as claimed in claim 5 comprising a first Caesium Bromide lens of positive optical power and a second Zinc Selenide lens of negative optical power; the two lenses being separated by a relatively narrow air-gap.

7. A Thermal Imager, including a lens system as claimed in any of the preceding claims.

8. A lens system as claimed in claim 5 having the structure shown in Figure 4 of the accompanying drawings.

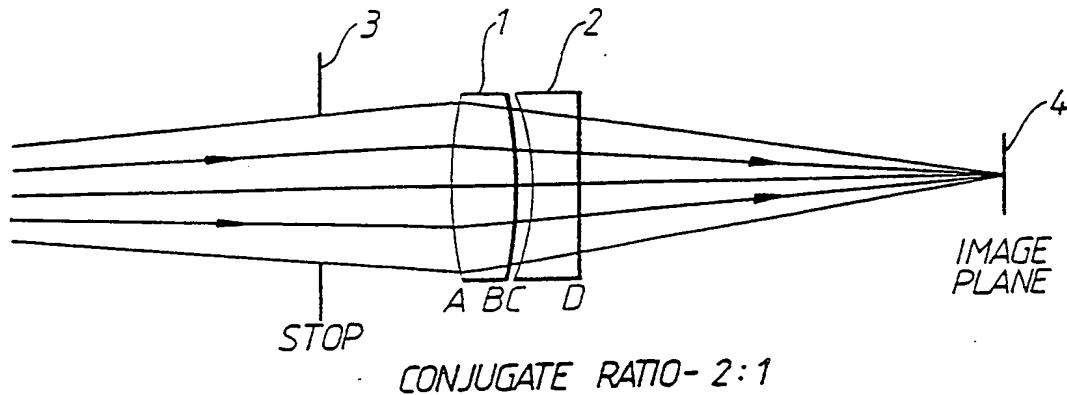


FIG. 1.

SURFACE	RADIUS	THICKNESS	APERTURE	MATERIAL
OBJECT	∞	65.761		AIR
STOP	∞	9.000	6.000	AIR
A	36.51	5.000	7.000	Zn Se
B	-36.51	0.965	7.000	AIR
C	-26.13	4.000	7.000	ZnS
D	-167.67	31.580	7.000	AIR
IMAGE	∞	—	—	AIR

EQUIVALENT FOCAL LENGTH 24.58

FIG. 2.

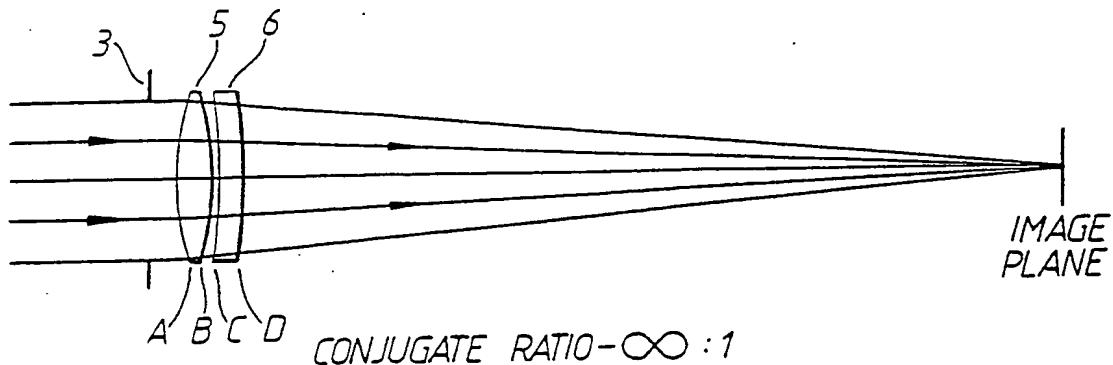


FIG.3.

SURFACE	RADIUS	THICKNESS	APERTURE	MATERIAL
OBJECT	∞	∞	—	AIR
STOP	∞	0.000	12.500	AIR
A	85.115	4.000	13.000	Cs Br
B	-99.762	1.000	13.000	AIR
C	-93	4.000	13.000	Zn Se
D	-164.595	120.954	13.000	AIR
IMAGE	∞	—	—	AIR

EQUIVALENT FOCAL LENGTH 124.969

FIG.4.



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㉘ Designated Contracting States: BE DE ES FR IT

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㉛ Lens system usable in the IR.

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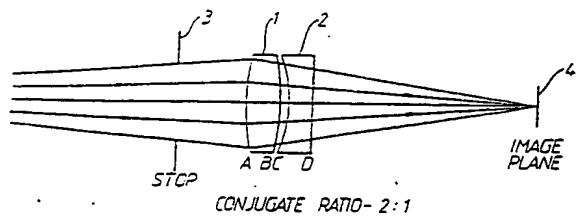


FIG. 1.

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DOCUMENTS CONSIDERED TO BE RELEVANT												
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 4)									
X	OPTICAL ENGINEERING vol. 23, no. 2, March/April 1984, pages 111-116, Bellingham, Washington, USA; T.H. JAMIESON: "Ultrawide waveband optics." * abstract; item 4.2; table V(a); figures 3(b), 7 *	1, 5, 6	G 02 B 13/14 G 02 B 9/10									
Y	idem	2										
A	idem ---	3, 7										
Y	LASER FOCUS December 1976, pages 47-50; F.M. LUSSIER: "Guide to ir-transmissive materials". * figure 1, table 1 *	2										
A	APPLIED OPTICS vol. 20, no. 24, December 1981, pages 4143-44, New York, USA; A.C. WALKER: "Achromatic doublets for simultaneous imaging or IR (10.6-micro-m) and visible (0.6328-micro-m) radiation". * in total *	1										
A	---											
A	US-A-3 622 218 (H.G. KRUEGER) * abstract; figure 1; column 1, lines 10-35 *	1	G 02 B 1/00 G 02 B 9/00 G 02 B 13/00 G 02 B 23/00									
A	US-A-3 674 330 (J.D. STRONG) * abstract; column 1, line 70 - column 2, line 15; claim 1 *	1										

<p>The present search report has been drawn up for all claims</p> <table border="1"> <tr> <td>Place of search BERLIN</td> <td>Date of completion of the search 15-03-1989</td> <td>Examiner HYLLA W.A.</td> </tr> <tr> <td colspan="3">CATEGORY OF CITED DOCUMENTS</td> </tr> <tr> <td colspan="2">X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</td> <td>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document</td> </tr> </table>				Place of search BERLIN	Date of completion of the search 15-03-1989	Examiner HYLLA W.A.	CATEGORY OF CITED DOCUMENTS			X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document
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